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This report describes tests for a type of Doppler radar system referred to as a radar chronograph. Radar chronographs, such as the M90, are used by the U.S. Army for measuring muzzle velocity in field artillery applications. Included in this TOP are testing and data-reduction procedures for the following subtests: laboratory electronic, field operation, adverse condition, transportability, reliability, maintenance, safety, and human factors.

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TEST OPERATIONS PROCEDURE

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AD No.

CHRONOGRAPH, FIELD ARTILLERY

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1. SCOPE. This TOP describes tests for a type of Doppler radar system referred to as a radar chronograph. Radar chronographs, such as the M90, are used by the U.S. Army for measuring muzzle velocity in field artillery applications. Included in this TOP are testing and data-reduction procedures for the following subtests: laboratory electronic, field operation, adverse condition, transportability, reliability, maintenance, safety, and human factors.

2. FACILITIES AND INSTRUMENTATION.

2. Facilities.

ITEM	REQUIREMENTS
Weapons and ammunition	As required
Environmental test chambers	See MIL-STD-810D[1]**
Laboratory electronic testing facilities	
Shock test facilities	Shock machines/testers, test fixtures, transducers, oscilloscope-cameras, or multi-band recorders, X-ray inspection equipment, arresting media (see MTP 5-2-506[2])

*Supersedes MTP 6-2-034 dated 17 September 1968.

**Footnote numbers/letters correspond to those in Appendix C.

ITEM (cont'd)	REQUIREMENTS (cont'd)
Vibration test facilities	Vibrator/exciter, rigid fixtures, recording system, signal-conditioning equipment, piezoelectric accelerometers (see MTP 5-2-507')
Firing range	Cleared of obstructions for 2500m; equipped with instrumentation to verify that the chronographs are accurately measuring muzzle velocity (TOP 4-2-805*): a Digital Doppler Test Site Terminal (DDTST), Doppler velocity simulator, or a Weibel radar system should be used.
Transportability test facilities	See TOP 1-2-500.*

2.2 Instrumentation.

DEVICE FOR MEASURING:	PERMISSIBLE ERROR OF MEASUREMENT*
Voltage, amperage, resistance (e.g., multimeters)	5% of full scale
Wave length (e.g., oscilloscopes)	3% of full scale
Frequency (e.g., frequency counters)	0.05% of frequency measured
Time intervals (e.g., time interval counters)	±1 digit
Radio frequency power (e.g., RF power meters)	1% of full scale
Size of radio beam (e.g., microwave horns)	±1°
Projectile velocity (e.g., velocimeter or sky screens)	0.2% of velocity measured
Test events (e.g., high speed cameras)	As required
Meteorological data (barometers, anemometers, etc.)	As required

*The permissible error of measurement for instrumentation is the two-sigma value for a normal distribution. Thus the stated errors should not be exceeded in more than one measurement of 20.

3. REQUIRED TEST CONDITIONS.

3.1 Reference Material. The following materials are recommended for review before testing begins:

a. Safety Assessment Report (SAR). This document is required by AR 385-16[6] and should contain any hazards identified by the developer or contractor.

b. Materiel Safety Data Sheet (MSDS).

c. Technical manuals describing the function, operation, and specifications of the test item.

d. Operating instructions and standing operating procedures (SOPs) for all instrumentation used.

e. Reports of previous Doppler system tests and related tests.

f. Inspection checklists that cover common types of unsafe conditions are contained in Appendix C of TOP 1-1-060.[7] Also check other system-peculiar TOPs. When checklists as described above do not adequately cover the test item, appropriate checklists can be developed as described in Appendix C of TOP 1-1-060.

g. All applicable TOPs. The following TOPs provide some pertinent background information on general radar characteristics:

TOP No.	Title
4-1-005[a]	The Doppler Velocimeter
6-2-020[8]	Radar Antenna Tests
6-2-220[b]	Radar Field Artillery
6-2-222[c]	Radar, Target and Ranging
6-2-558[d]	R.F. Power Output
7-3-524[9]	Radar Reflectivity

3.2 Inspection. Upon receipt, the following procedure will be used to inspect the test item:

a. Photograph the packaged test item to record the "as received" condition.

b. Measure and record the size and weight of the packaged test item including cable lengths.

c. Unpack and inspect the test item and its components. Record the following:

(1) Nomenclature

(2) Model number

(3) Serial number

(4) Manufacturer

(5) All evidence of physical or electrical damage such as damaged parts, corrosion, scratches, chips, dents, loose connections, bare or broken wires, loose assemblies, etc.

(6) The adequacy of the type of protection for the item during transport and storage.

d. Photograph the unpackaged test item to record its "as received" condition.

e. Review all documentation received with the test item.

f. Check the shipping inventory and basic issue items list to ensure that all equipment, tools, spare parts, and test instruments were obtained with the test item.

g. Perform a safety inspection of the test item before beginning the test. Safety engineering assistance may be requested, as required, through the appropriate safety office.

h. Operate all operator controls and mechanical features in the "power off" mode to ensure proper operation. After proper operation has been verified, apply power to the system, and repeat the check. Record all malfunctions.

i. Check if test item meets criteria and requirements of MIL-STD-454K.[10]

j. Return chronograph and associated equipment to the container and case until ready for operational setup.

4. TEST PROCEDURES.

4.1 Laboratory Electronic Tests. NOTE: Component failure of the set in any phase of laboratory testing and subsequent repairs, adjustments, or modifications can void earlier data. It is extremely important to ensure that areas which are repaired, as well as related areas, are adequately re-tested.

4.1.1 Operational Checkout. This consists of the initial power application and corresponding checkout procedures to determine any readily apparent discrepancies and the performance of initial adjustments, as required.

Using the operator's check-out instructions, perform the following:

a. Ensure that a proper power supply is available as specified by the voltage, frequency, harmonic distortion, and power requirements of the radar.

b. Apply power to the test item, and immediately check indicating meters for proper readings. Also listen for any unusual noise or absence of noise that should be present (e.g., by cooling fans).

c. Perform any internal adjustments required to bring various meter readings within tolerances.

NOTE: Any controls previously set and critical to performance should not be changed.

4.1.2 Transmitter Test. This is an electronic evaluation of the test item's transmitter characteristics.

a. Connect a directional coupler to the waveguide between the transmitter and antenna system.

b. Perform transmitter tests described in MTP 5-2-530.[11]

NOTE: Since instrumentation that operates on the Doppler principle requires extremely stable signal generators, particular attention should be given to the frequency accuracy and stability test.

4.1.3 Receiver Test. This is an electronic evaluation of the test item's receiver characteristics.

a. Connect a directional coupler to the waveguide between the receiver and the antenna system.

b. Subject the radar chronograph's receiver portion to the applicable tests of MTP 5-2-529.[12]

NOTES:

1. Particular attention should be given to determining the receiver's frequency response and sensitivity, automatic frequency control (AFC) operation, automatic gain control (AGC) operation, and the velocity filter bandwidths, as required.

2. The receiver sensitivity test determines the minimum signal to which the set will respond properly.

3. The Doppler frequency response may be sampled during the receiver sensitivity test, but the test frequencies sampled must be selected carefully since one or more circuits may not respond equally to all required frequencies.

4.1.4 Antenna Test. This is an electronic evaluation of the test item's wave guide-antenna characteristics.

a. Connect a directional coupler to the waveguide between the antenna system and the transmitter/receiver.

b. Subject the radar chronograph's wave guide-antenna system to the applicable tests of TOP 6-2-020 including measurements of the voltage standing wave ratio (VSWR).

4.1.5 Electromagnetic Compatibility. This test determines the electrical compatibility of the module portions (i.e., transmitter, receiver, antenna) of the unit test item and the unit's compatibility with applicable exterior equipment.

While monitoring the applicable measurable chronograph characteristics of paragraphs 4.1.2, 4.1.3, and 4.1.4, perform the following:

a. Subject the test item, as a unit, to the applicable tests of TOP 6-2-560[13] to determine the electrical compatibility of the transmitter-receiver-antenna combination.

NOTE: The unit's interior compatibility test should include, in particular, measurements concerning the transmitter signal leakage into the receiver.

b. Subject the test item, as a unit, to the appropriate tests to determine its effect on the environment.

4.1.6 Power Requirements. This test determines the effects of input power variations upon the test item's operation.

While monitoring the applicable measurable chronograph parameters of paragraphs 4.1.2, 4.1.3, and 4.1.4, subject the test item to applicable tests of TOP 6-2-514[14] to determine the test item's sensitivity to input power variations.

NOTES: 1. Input power frequency and voltage variations, within the established tolerance limits of the set, may deteriorate the power output, receiver sensitivity, or other parameters to less than the required limits.

2. Care must be taken in conducting this test to ensure that no critical combination of voltage and frequency is omitted.

4.2 Field Operation Tests.

4.2.1 Alignment, Installation and Operational Checkout.

a. Install and align the test item in accordance with the technical manuals.

b. Perform the operational checkout procedures described in the technical manuals.

c. If possible, provide a simulated Doppler signal to the test item to determine how accurately the test item interprets the signal.

4.2.2 Trial Firing. Accuracy tests should be preceded by non-instrumented field trials. If the field trials indicate gross errors in the readout data and other operational problems, instrumented field trials are not required.

a. Fire at least five rounds (either all the same type or five different rounds of known muzzle velocity).

b. Verify the proper operation of the test item by comparing the output data with the estimates of projectile velocity.

NOTE: The shock and vibration may cause switches and connectors to open momentarily and other parts to fail physically, thus disrupting or degrading subsequent performance. Structural damage could occur to the waveguide section which would degrade the sensitivity of the unit.

4.2.3 Accuracy and Imprecision Test. Evaluate the accuracy of the test item by comparing its output data to that of two independent velocity measurement systems of known accuracy capable of assessing the subject chronograph (e.g., DDTST, Weibel radar system, or sky screens).

Conduct a comprehensive firing program using various weapon charge combinations and a variety of projectile shapes and sizes. A wide range of muzzle velocities and radar cross-sections is desired.

4.2.4 Performance Tests. These determine the range of velocities and the maximum distance at which the test item can make acceptable measurements.

a. Fire a variety of projectile-charge combinations so that the test item is required to measure extremely low and high projectile velocities.

b. Fire projectiles at a fixed elevation. Re-aim the test item after each round so that the radar beam intersects the trajectory at a farther range. Repeat this until the maximum range of the test item is obtained.

4.3 Adverse Condition Tests.

4.3.1 Environmental Tests. These tests determine whether system performance is degraded when the test item is subjected to particular simulated environments.

Conduct the following tests in accordance with MIL-STD-810D:

a. High temperature tests (Method 501.2, Procedures I and II)

b. Low temperature tests (Method 502.2, Procedures I and II)

c. Humidity tests (Method 507.2, Procedure I or III)

d. Fungus tests (Method 508.3)

e. Salt fog tests (Method 509.2)

f. Rain tests (Method 506.2, Procedure I)

4.4 Transportability Test. This determines transport effects on the test item's physical and operational characteristics.

Determine the transportability of the test item in accordance with TOP 1-2-500. The test documentation, test sponsor, or item user should provide information about the test item's operational environment. Once the operational environment is known, the tests described in TOP 1-2-500 can be tailored accordingly.

4.5 Reliability Evaluation. This test determines if the test item meets reliability specifications.

Use MTP 6-2-503[18] for general guidance in tailoring the test to the test item requirements. (At USACSTA, the Systems Analysis Branch can provide input for the number of measurements required, based on the number of test items and test criteria.) The possibility of combining the firing portion of this evaluation with ongoing ammunition tests should be considered. This will alleviate the necessity of obtaining rounds for test and will also efficiently employ support instrumentation.

4.6 Maintainability. This test evaluates the test item's maintainability characteristics. It will identify maintenance requirements, describe the ease of performing maintenance actions, and identify any special tool requirements.

Follow the procedures in MTP 6-2-504[16] in designing this test. Qualified maintenance personnel are required for testing; these personnel should be contractor/developer-trained.

4.7 Safety and Health Evaluation. This test will uncover any hazards associated with the design and operation of the system. Conduct according to TOP 1-1-060.

a. Examine the test item to confirm the safety release.

b. Use MTP 3-2-616[17] to determine radio frequency (RF) radiation hazards to test personnel. The Army Environmental Hygiene Agency (AEHA) can provide assistance with this.

c. Determine any other hazards associated with the use of RF waves that may occur during tests. This includes hazards associated with the use of RF waves in the same area as proximity fuzes and electromagnetic interference.

d. Ensure that all warning labels for high voltages and hazardous materials are in place.

e. Based upon the results of the safety inspection(s), hazard analysis, test results, comments from operating and maintenance personnel, and a review of all supporting documentation, evaluate the hazards in accordance with Appendix C of TOP 1-1-060.

4.8 Human Factors Evaluation. This concerns the human factors aspects of the test item in its employment and operation. Test criteria should be provided with the test documentation from TECOM or the test sponsor.

Perform a human factors investigation according to TOP 1-2-610.[18] Particular attention should be given to the readability of any output displays and test item adjustments.

5. DATA REQUIRED. Record/obtain the following data as specified under each subtest:

5.1 Laboratory Electronic Tests.

5.1.1 Operational Checkout.

a. Type and model number of power supply

b. Failures during checkout

c. Improper operations

d. Internal adjustments made, if any.

5.1.2 Transmitter Test. Record the data according to MTP 5-2-530.

5.1.3 Receiver Test. Record the data according to MTP 5-2-529.

5.1.4 Antenna Test. Record the data according to MTP 6-2-020.

5.1.5 Electromagnetic Compatibility. Record all data regarding compatibility/incompatibility with exterior equipment. Perform an equipment search as described in TOP 6-2-560 to determine other electrical equipment which operates at the frequencies measured above.

5.1.6 Power Requirements. Record the data according to MTP 6-2-514.

5.2 Field Operation Tests.

5.2.1 Alignment, Installation, and Operational Checkout.

a. Weapon type

b. Radar chronograph type

c. Outstanding terrain features

d. Alignment procedure for test item

e. Type and model number of power supply

f. Any failures during checkout

g. Any internal adjustments

5.2.2 Trial Firing. Record the following on a round-by-round basis:

a. Firing weapon identification

b. Projectile characteristics:

(1) Type

(2) Description of RF reflective characteristics and/or quantitive data, if available.

(3) Charge identification and weight.

(4) Expected muzzle velocity

c. Test item characteristics:

(1) Observations of internal meter readings.

(2) Projectile velocity versus time data from test item's readout.

(3) Any noticeable shock or blast damage.

5.2.3 Accuracy and Imprecision Test. Record the following for each round fired:

a. Firing weapon identification

b. Projectile characteristics:

(1) Type

(2) Description of RF reflective characteristics and/or quantitative data, if available

(3) Charge identification and weight

c. Test item characteristics:

(1) Observations of internal meter readings

(2) Projectile velocity versus time data from test item output data

(3) Any noticeable shock or blast damage

d. Calculated and measured values from the velocity measurement instrumentation

e. Meteorological data:

(1) Air density (kg/m')

(2) Air temperature (°C)

(3) Barometric pressure (in millibars)

(4) Relative humidity (%)

(5) Wind direction and speed at time of fire in m/s (To be useful, this will require multiple wind sensors elevated so that they are as close as possible to the bullet's flight path.)

(6) Test site altitude

(7) Time of fire

f. Distance from the muzzle to the sensors (sky screens, radar, etc.)

g. Sensor output:

(1) For sky screens - sky screen times

(2) For the DDTST - velocity versus time data

5.2.4 Performance Tests.

a. Minimum velocity which test item is capable of measuring

b. Specified minimum velocity

c. Maximum range at which test item is capable of measuring

d. Specified maximum range

e. Any noticeable shock or blast damage to the test item

f. Any failure of the radar chronograph to determine velocity of a projectile

g. Any component failures encountered during testing

5.3 Adverse Condition Tests.

5.3.1 Environmental Tests.

a. Type of environmental test (humidity, fungus, etc.)

b. Data collected in accordance with MIL-STD-810D.

c. For each firing trial, record the following:

(1) Firing weapon identification

(2) Projectile characteristics:

(a) Type

(b) Description of RF reflective characteristics and/or quantitative data, if available

(c) Charge identification and weight

(3) Test item characteristics:

(a) Observations of internal meter readings

(b) Projectile velocity versus time data from test item output data

(c) Any noticeable shock or blast damage

(4) Calculated and measured values from the velocity measurement instrumentation

(5) Meteorological data:

(a) Air density (kg/m^3)

(b) Air temperature (°C)

(c) Barometric pressure (millibars)

(d) Relative humidity (%)

(e) Wind direction and speed at time of fire in m/s; to be useful, this will require multiple wind sensors elevated so that they are as close as possible to the bullet's flight path

(f) Test site altitude

(g) Time of fire

(6) Distance from the muzzle to sensors (sky screens, radar, etc.)

(7) Sensor output:

(a) For sky screens - sky screen times

(b) For the DDTST - velocity versus time data

(8) Any estimated or calculated values used to verify results

5.4 Transportability Test. Record data in accordance with TOP 1-2-500.

5.5 Reliability Evaluation.

a. Initial operation data for the test item (e.g., rounds, hours, miles)

b. Logbook containing pertinent test observations about system operation. These should be in chronological order and dated.

c. Any meter readings and self-test results (if available) for each operational checkout

d. Test Incident Reports (TIRs) for each failure or significant test event. These should include time, date, round life, and time life at time of event and for item failures at the time of return to the test item.

e. Data as described in MTP 6-2-503.

5.6 Maintainability.

a. Keep a logbook detailing all maintenance actions and times; this will help when writing TIRs and during scoring conferences.

b. TIRs for each maintenance action

c. List of any tools required to perform the repair

d. Maintenance level

e. Other data described in MTP 6-2-504.

5.7 Safety and Health Evaluation.

a. Data as required in TOP 1-1-060

b. Photographs of all identified hazards

c. Observations of operating and maintenance personnel

d. Completed checklist in Appendix B.

e. Completed electrical safety checklist

5.8 Human Factors Evaluation. Record data according to TOP 1-2-610.

6. PRESENTATION OF DATA.

a. Failure of the test item to meet specified electrical and safety criteria shall be recorded and possible causes determined. Safety hazards shall be categorized according to MIL-STD-882B[19] and TOP 1-1-012.[20] These findings will be a combination of observations taken throughout all phases of testing.

b. Data obtained from the standard velocity check instrumentation shall be reduced as described in TOP 4-2-805 to obtain the projectile's velocity versus time history. The DDTST already incorporates the software required to perform this computation and can provide this information in near real time. If sky screens are used, ballistic data for the rounds fired will be required. Accumulate the required data and compute the velocity versus time history. Compare the velocities from the standards to the test item velocities to yield a difference between readings. The imprecision can then be estimated using the procedure in Appendix A. Tabulate the imprecision data as a function of range, projectile, charge, weapon, etc. Range information for each reading can be obtained by integrating the velocity versus time information to yield range versus time and then solving for the time of each estimate. The DDTST, again, is capable of this computation for the reference data. If the test item does not have gross errors in velocity measurement, solving the DDTST's range versus time equations will give an adequate estimate of the projectile range at the time of measurement.

c. Descriptive evaluations of the test item's performance under adverse conditions will be provided. These evaluations shall document any performance degradation observed. This shall be presented as a percent error from a standard. For the case of muzzle velocity, this would be

$$\% \text{ error} = \frac{MVT - MVS}{MVS} * 100$$

in which

MVS = muzzle velocity from the standard
MVT = muzzle velocity from the test item

Also, any degradation from the percent error in the accuracy portion of the test should be reported.

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APPENDIX A

STATISTICAL PROCEDURES

The estimate of imprecision for the reference items, when assuming data are from the same population, may be written:

$$\sigma_A = \sigma_B = S_{A-B} / \sqrt{2}$$

in which

σ_A = estimate of imprecision for reference set A.
σ_B = estimate of imprecision for reference set B.
S_{A-B} = sample standard deviation of the difference between set A and set B.

The estimate of average level for the reference items may be written:

$$\overline{V_R} = 1/2\ (\overline{V_A} + \overline{V_B})$$

The estimate of imprecision for the test item may be written:

$$\sigma_T = \left[S^2_{T-0.5(A+B)} - 0.25\ S^2_{A-B} \right]^{1/2}$$

in which

$S^2_{T-0.5(A+B)}$ = sample variance of the difference between the test item and the average of the reference (set A and set B).

$S^2_{(A-B)}$ = sample variance of the difference between the reference (set A and set B).

The average level of the test is assessed based on the difference between the average level of the test and the average level of reference expressed as a percent of the average level of the reference. These tests should be applied in accordance with reference i.

APPENDIX B

HAZARD ANALYSIS

1. Can someone be struck by some moving object in the system?

   Look for: -normally moving objects
   -normally stationary objects.

2. Can someone strike against some object?

   Look for: -protruding objects
   -permanent objects requiring an effort to avoid
   -cramped work areas
   -manipulations that require great effort.

3. Can someone be caught between two objects?

   Look for: -a normally moving object approaching a stationary one
   -a normally stationary object forced to move
   -two normally moving objects contacting

4. Can someone be contacted by a substance that can cause injury?

   Look for: -hot or cold surfaces
   -electrically charged equipment
   -corrosive chemicals
   -exhaust fumes.

5. Can someone be exposed to a harmful condition?

   Look for: -toxic gases, fumes or vapors
   -air-borne particles
   -extreme heat or cold
   -oxygen-deficient atmosphere
   -radioactive radiation
   -intense light.
   -high noise level
   -blast overpressure

6. Can someone slip, trip or fall?

7. Can someone be over-exerted?

   Look for: -manual handling of heavy objects
   -imbalanced equipment.

8. Can someone be caught in/on something?

   Look for: -single-entry enclosures
   -small exposed floor openings
   -tight or cramped places
   -stationary or moving projecting objects.

9. Can someone be exposed to any energetic materials?

Look for: -explosives
-flammable or combustible materials
-hydraulic components
-pressure vessels.

APPENDIX C

REFERENCES

Required References

1. MIL-STD-810D, Environmental Test Methods and Engineering Guidelines, 19 July 1983; Notice 1, 31 Jul 86.

2. MTP 5-2-506, Shock Test Procedures, December 1966.

3. MTP 5-2-507, Vibration Test, 10 April 1967.

4. TOP 4-2-805, Projectile Velocity Measurements, 21 September 1982.

5. TOP 1-2-500, Transportability, 7 February 1973; Change 1, 22 July 1976; Change 2, 24 August 1976; Change 3, 20 March 1979.

6. AR 385-16, System Safety Engineering and Management, 3 September 1985; AR Suppl 1, 1 Dec 86; AMC Suppl 1, 22 Jan 82; TECOM Suppl 1, 11 Jun 82; and APG Suppl 1, 5 Jan 83.

7. TOP 1-1-060, System Safety Engineering, 7 April 1986.

8. ITOP 6-2-020, Radar Antenna Tests, 15 April 1988.

9. TOP 7-3-524, Radar Reflectivity, 10 June 1986.

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11. MTP 5-2-530, Transmitter Tests, 5 December 1967.

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13. TOP 6-2-560, Compatibility, Electromagnetic, 12 October 1979.

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15. MTP 6-2-503, Reliability, 23 March 1970.

16. MTP 6-2-504, Maintenance/Maintainability, 25 March 1970.

17. MTP 3-2-616, Radio Frequency Radiation Hazards to Personnel, 12 June 1968.

18. TOP 1-2-610, Human Factors Engineering, Part I, Test Procedures; Part II, Human Factors Engineering Data Guide for Evaluation (HEDGE), 30 November 1983.

19. MIL-STD-882B, System Safety Program Requirements, 30 March 1984; Notice 1, 1 Jul 87.

20. TOP 1-1-012, Classification of Deficiencies and Shortcomings, 1 April 1979; Change 1, 4 Nov 81; Change 2, 26 Nov 82; Change 3, 3 Dec 85.

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